



A COMPARISON BETWEEN TWO DIFFERENT TYPES OF ATTACHMENTS IN IMPLANT RETAINED MANDIBULAR OVERDENTURES (A STRESS ANALYSIS STUDY)

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ABSTRACT

Background: The target of this in vitro study was to evaluate the distribution of stresses using strain gauges around two mandibular implants installed in the inter-foraminal region retaining an overdenture with two different types of attachments; ball attachment and magnet attachment.

Materials and Methods: In this Invitro study, a mandibular conventional denture model was constructed using heat cured acrylic resin. In the canine region, two box shaped preparations with a 1mm thickness buccally, lingually, mesially and distally were done into which two dummy implants were mounted and bonded to the model using self-cure acrylic resin. Over each surface, strain gauges of length 5mm, resistance of $120.4 \pm 0.4 \Omega$ and a gauge factor of $2.09 \pm 1 \%$, were anchored. Unilateral and bilateral vertical static load of 100N using a universal testing machine was applied onto both types of overdentures; one retained by the ball and one by the magnet and 10 readings were recorded for each attachment.

Results: When comparing the micro strain mean values of both groups while applying strain both bilaterally and unilaterally, the study has shown that there was a statistically significant difference in the mean values of micro strain between the Ball and Magnet attachment in the non-loading side where ($p < 0.001$). The highest mean value of micro strain was found in Ball attachment while the least mean value of micro strain was found in the Magnet in both events. Results also revealed that there was a statistically significant difference in mean values of micro strain between the Loaded side and the Unloaded side where ($p < 0.001$) where The highest mean value of micro strain was found in the Loaded side while the least mean value of micro strain was found in Unloaded side in both groups.

Conclusion: Within the limitations of this study, it can be concluded that ball attachments induce higher micro-strain on the bone implant interface than the magnet attachment.

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INTRODUCTION

The ideal goal for modern dentistry is to restore the patient's normal facial contour, function, comfort, esthetics, speech and health.^[1] The increasing need and use of dental implant-related treatments result from the combined effect of a number of factors as mentioned by Misch⁽¹⁾. The use of dental implants to restore completely edentulous patients has greatly improved patient satisfaction, masticatory performance, health of remaining supporting structures and overall quality of life for edentulous patients⁽²⁻⁴⁾. Implant retained overdentures using two inter-foraminal implants have been recognized to be the standard of care for completely edentulous patients since 2002⁽²⁾ for being simple, less invasive, cost-effective and successful^(5,6).

Attachments used to retain Implant supported overdentures can be mainly classified into splinted attachments or un-splinted attachments⁽⁷⁾. The un-splinted attachments have a greater advantage of less inter-arch space requirement, ease of cleaning, cheaper and easier to construct than the splinted attachments^(8,9).

Ball and socket attachment is the most well-known un-splinted attachment to retain a mandibular overdenture, because of its simplicity and low cost⁽¹⁰⁾. Masticatory functional load are normally transferred through the implants to the peri-implant bone⁽¹¹⁾. Brunski^[12] declared that controlling the functional forces is a contributing factor for obtaining success of implant. In a series of experiments, Miyata et al.^[13] conducted experiments that showed that occlusal overload can result in marginal bone loss around oral implants with no inflammation in the peri-implant tissues.

There are several types of attachments including bars, rigid and resilient telescopes, magnets and stud attachments^(14,15). Magnetic attachments have the advantage of self-aligning properties as well as their low vertical profile rendering them particularly useful in patients with physical disabilities⁽¹⁶⁾ or

where inter-occlusal space is a problem⁽¹⁷⁾. However, Magnet attachments have low resistance to lateral forces due to their ability to immediately disengage thus eliminates the lateral forces and conveys the least stresses conducted to the per-implant bone when compared with other attachments⁽¹⁸⁾. This means that their retentive forces were less than other attachments^(18,19). According to Tokuhisa et al. and Takeshita et al.^(18,19), Magnet attachments were found to exhibit the least strains under occlusal loading when compared to ball and bar attachments. Moreover, Ball attachments for implant-retained overdentures were associated with significant mandibular denture base deformation over the implants compared to Locator attachments⁽²⁰⁾. In a recent study performed by Takahashi et al.⁽²¹⁾, results demonstrated that Ball attachments caused the greatest amount of strain, while magnet attachments caused the least amount under all conditions. Another great advantage of magnet attachment is that their retentive property is never ending due to the very long time span of its magnetic field in comparison with other stud attachments which are subjected to component wear due to friction⁽¹⁸⁾.

Despite all these studies, a systematic review performed by Anas el Wegoud et al.⁽²²⁾ concluded that there is still insufficient evidence to support bar or ball attachment to be used with implant-supported overdentures in completely edentulous patients to improve patient satisfaction and prosthesis retention.

Analysis of the stresses transmitted to the peri-implants can be done using several methods including photo elastic, strain gauge and finite element analysis. Strain gauges work by calculating the distortion of a body by computing its electrical resistance alteration providing quantitative data⁽²³⁾. It will then transform the change in electrical resistance to an electrical voltage which can be measured with great accuracy at the place where the strain gauge is placed^(24,25). However, the size and placement of the strain gauges are critical and could be a limiting factor⁽²³⁾.

MATERIALS AND METHODS

I. Model construction and Implant placement

In this In vitro study, a mandibular conventional denture model was constructed using heat cured acrylic resin*. In the canine region, two box shaped preparations with a 1mm thickness buccally, lingually, mesially and distally were done into which two dummy implants were mounted and bonded to the model using self-cure acrylic resin**. Over each surface, strain gauges of length 5mm, resistance of $120.4 \pm 0.4 \Omega$ and a gauge factor of $2.09 \pm 1 \%$, were anchored. Unilateral and bilateral vertical static load of 100N using a universal testing machine was applied onto both types of overdentures; one retained by the ball and one by the magnet and 10 readings were recorded for each attachment.

In this In vitro study, a completely edentulous mandibular model was constructed using heat cured acrylic resin using a silicon mold duplicated from a conventional mandibular cast. A properly adapted and stable trial denture base was then fabricated using self cured acrylic resin on this acrylic resin mold. Teeth selection and set up was then performed on the trial denture base following the conventional guide lines of complete denture construction. Waxing up, flasking packing and curing was then performed in a conventional manner followed by de-flasking and finishing and polishing of the final acrylic mandibular denture. The mandibular denture was then duplicated into a clear acrylic resin stent after being checked for proper fit and seating on the acrylic model. Drilling of the clear acrylic resin was carried out from the right canine area and left canine area while keeping the labial and lingual surface intact. Two mock implants were then mounted on the right

and left canine area using a surveyor milling machine*** to ensure parallelism of the two implants. The mock implants**** were connected to the cast by placing a soft mix of self-cure acrylic resin in the drilled holes during installation of the implants.

II. Model Preparation for Strain Gauges Placement

The acrylic resin was prepared using a fissure bur to create a box of 1 mm thickness around each of the two implants with four surfaces: Buccal (B), Lingual (L), Mesial (M), and Distal (D). The walls prepared were smooth (smoothened with sandpaper to avoid incremental strains) flat and parallel to the long axis of each installed implant. Since the used strain gauges were temperature-compensated for plastics, a dummy gauge was not used for temperature compensation⁽²⁶⁾ (Stegaroiu et al., 2004).

The Strain gauges***** installed were 5mm in length, resistance of $120.4 \pm 0.4 \Omega$ and a gauge factor of $2.09 \pm 1 \%$. The strain gauges were labeled according to each surface it was attached to then adhered to the four prepared surfaces using a Cyanoacrylate based adhesive***** and was left 24 hours to fully set. The Strain gauges were secured in special Channels prepared on the sides of each model to prevent no any damages or dislodgment during the measurement procedure.

Attachments pick up

The two attachments used in this in vitro study were the; Ball and Magnet attachment. First, the two ball attachments with their metal housing and nylon cap were placed over the two implants. The ball attachments were screwed with a torque of 25Ncm (Fig.1A). Two holes corresponding to each of the ball attachment with their metal housing were

* Clear heat cured acrylic resin, Acrostone, Egypt

** Cold cure Acrylic resin, Acrostone, Egypt

*** Bego Bremer Goldschagerei Wihl. Herbst, Bremen, Germany

**** Osteoseal dental implants, California, USA

***** Kyowa strain gauges, KFG-3-120-c1-11L1M2R, Japan

***** CC-33 strain gauge cement, Kyowa electronic instruments co., Japan.

prepared on the fitting surface of the lower denture. The complete denture was checked for complete seating and lack of any interference between the metal housing and fitting surface. A rubber dam was positioned around each of the ball attachments to block the undercuts during pick up. Pick up procedures were initiated for the ball attachment followed by loading and measurements. A thin mix of self-cure acrylic resin was placed through the drilled holes of the properly seated denture. The denture was removed from the cast with the metal housing and nylon cap and was checked to be properly picked up in the fitting surface of the denture (Fig. 1 B).

Measurements of the strain around each implant were then recorded for the ball attachment group. After all of the measurements were recorded, the metal housing with nylon cap along with the surrounding acrylic resin was then removed from the fitting surface of the denture.

The ball attachment was unscrewed from the acrylic resin model, and the two Magnet attachments of 2mm gingival height were screwed to the two implants (Fig. 1 C) with a torque of 35Ncm. The magnetic keeper was placed over the attachment. Pick up of the Magnet attachments was done in a similar way to that done for the ball attachments (Fig. 1 D). The denture with the Magnet attachment was then used to measure all of the strains around each implant for this group.

III. Loading and Strain measurements

In this in vitro study, Unilateral and bilateral vertical static load of 100 N for 15 seconds at a cross head speed of 0.5mm/minute to simulate implant retained occlusal loads was performed using a universal testing machine.* A small round bur was

used to prepare a small notch in the central fossa of the first molar tooth on the right and left sides which functioned as a repeatable and standardized point of load application. (Fig. 2). An I-shaped load applicator was utilized for obtaining the unilateral loading readings where the load applicator was applied on the prepared notch of the first molar on the left side. The left side was considered to be the loading/working side, while the right side was considered to be the non-loading/non-working side. A T shaped load applicator was utilized for obtaining the bilateral loading readings where the load applicator was simultaneously applied on the prepared notch of the first molar on both the right and left sides of the arch (Fig. 3).

A multichannel strain meter** (Fig. 4) was connected to the terminal ends of the strain gauge wires. Using special software***, this Multichannel strain meter was used to measure the microstrains transmitted through each of the four strain gauges. Ten readings were taken for each of the two attachments allowing at least a five minute interval between each reading for heat dissipation. The results obtained were recorded, tabulated and statistically analyzed.

Statistical Method

The mean and standard deviation values were calculated for each group. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests and showed parametric (normal) distribution. Independent sample-t test was used to compare between independent samples. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

* Lloyd LR5K instrument, Fareham, Hampshire, UK

** Model 8692, Tinsely precision instruments, Surrey, UK

*** Kyowa Electronic Instruments Co.,Ltd, Japan

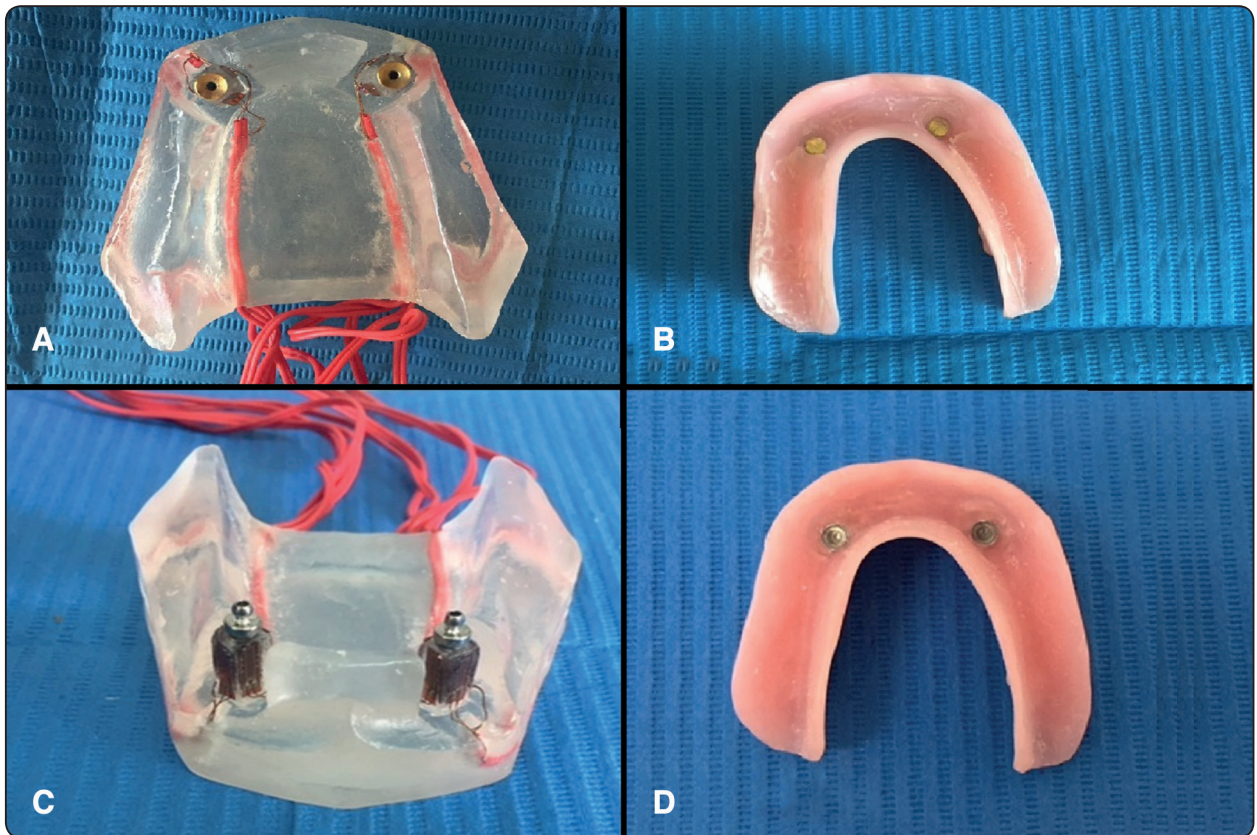


Fig (1) A) Magnet attachment screwed to the cast. B) Magnet keeper picked up in fitting surface of the denture C) Ball attachment screwed to the cast. D) Nylon cap picked up in the denture.

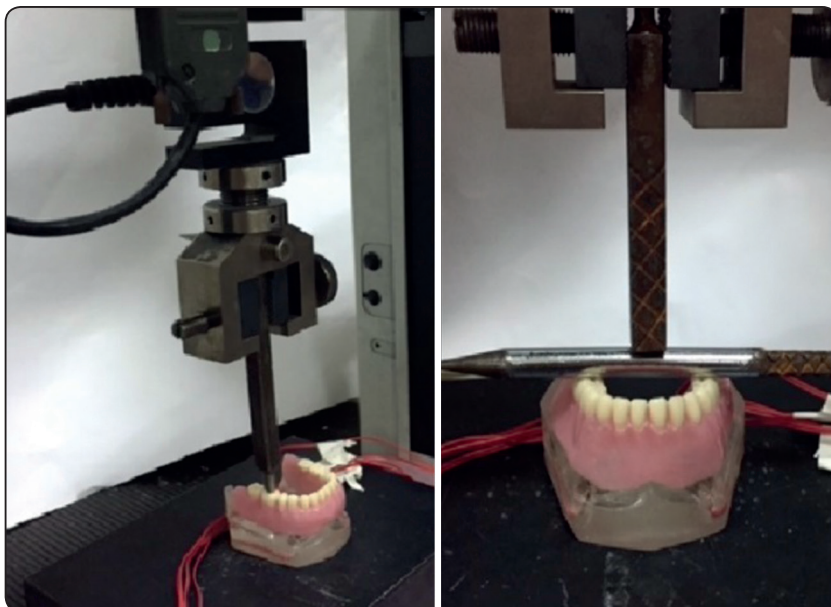


Fig (3) The Universal testing machine applying unilateral load

Fig (4) The Universal testing machine applying bilateral load



Fig (5) Multichannel Strain meter

RESULTS

There was no statistically significant difference in the mean micro-strain measurements recorded at the different surfaces; Buccal, Mesial, Distal, and Lingual for each implant. For that reason all of the four surfaces were added up to represent a mean micro-strain recorded for each implant.

Unilateral loading:

Regarding the Ball attachment group, there was a statistically significant difference in mean values of micro strain between the Loaded side and the Unloaded side where ($p < 0.001$). The highest mean value of micro strain was found in Loaded side while the least mean value of micro strain was found in

Unloaded side. (Table 1)

As for the for the Magnet attachment, there was a statistically significant difference in mean value of micro strain between Loaded side and Unloaded side where ($p < 0.001$). The highest mean value of micro strain was found in the Loaded side while the least mean value of micro strain was found in Unloaded side. (Table 1) (Fig. 5)

When comparing the micro strain mean values of both groups while applying strain unilaterally, the study has shown that there was a statistically significant difference in the mean values of micro strain between the Ball and Magnet attachment in the non-loading side where ($p < 0.001$). The highest mean value of micro strain was found in Ball attachment while the least mean value of micro strain was found in the Magnet attachment.

Additionally, statistical analysis of the micro strain mean values of both groups while applying strain unilaterally, showed a statistically significant difference in the mean of micro strain between the Ball and the Magnetic attachment at the loaded side where ($p < 0.001$). The highest mean value of micro strain was found in the Ball while the least mean value of micro strain was found in Magnet attachment. (Table 1) (Fig. 8)

TABLE (1): The mean, standard deviation (SD) values of micro strain of unilateral loading of both groups.

Variables	Unilateral loading				P-value
	Unloaded side		Loaded side		
	Mean	SD	Mean	SD	
Ball attachment	229.50 ^{aB}	33.52	864.50 ^{aA}	38.14	<0.001*
Magnetic attachment	153.50 ^{bB}	40.53	330.25 ^{bA}	56.60	<0.001*
P-value	<0.001*		<0.001*		

Means with different small letters in the same column indicate statistically significance difference; means with different capital letters in the same row indicate statistically significance difference. *; significant ($p < 0.05$) ns; non-significant ($p > 0.05$)

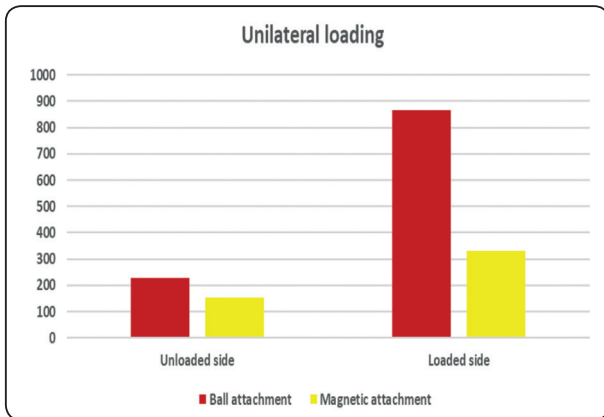


Fig. (6): Bar chart representing means of micro strain of unilateral loading in both groups

Bilateral loading:

Regarding the Ball attachment group, there was a statistically significant difference in mean values of micro strain between the Loaded side and the Unloaded side where ($p < 0.001$). The highest mean value of micro strain was found in Loaded side while the least mean value of micro strain was found in Unloaded side. (Table 2)

As for the for the Magnet attachment, there was a statistically significant difference in mean value

of micro strain between Loaded side and Unloaded side where ($p < 0.001$). The highest mean value of micro strain was found in the Loaded side while the least mean value of micro strain was found in Unloaded side.

When comparing the micro strain mean values of both groups while applying strain bilaterally, the study has shown that there was a statistically significant difference in the mean values of micro strain between the Ball and Magnet attachment in the non-loading side where ($p < 0.001$). The highest mean value of micro strain was found in Ball attachment while the least mean value of micro strain was found in the Magnet attachment.

Additionally, statistical analysis of the micro strain mean values of both groups while applying strain bilaterally, showed a statistically significant difference in mean of micro strain between the Ball and the Magnetic attachment at the loaded side where ($p < 0.001$). The highest mean value of micro strain was found in the Ball while the least mean value of micro strain was found in Magnet attachment. (Table 2)

TABLE (2): The mean, standard deviation (SD) values of micro strain of Bilateral loading of both groups.

Variables	Bilateral loading				P-value
	Unloaded side		Loaded side		
	Mean	SD	Mean	SD	
Ball attachment	368.75 ^{ab}	23.45	635.00 ^{aA}	80.48	<0.001*
Magnetic attachment	68.25 ^{bb}	8.63	127.00 ^{bA}	14.73	<0.001*
P-value	<0.001*		<0.001*		

Means with different small letters in the same column indicate statistically significance difference; means with different capital letters in the same row indicate statistically significance difference.

*; significant ($p < 0.05$) ns; non-significant ($p > 0.05$)

DISCUSSION

In the current study, all circumstances were standardized; the same denture was used for pickup of both attachments to decrease any variables such as the presences of any porosities or deformations in the denture base that might induce micro-strain.

In this current study, unilateral load was done to mimic the preferred chewing side of each patient while bilateral loading was done to mimic bilateral chewing. A wide range of multi-directional occlusal forces will be applied to implant supported overdentures as a result of masticatory and functional loads which will in turn induce strain to the peri-implant bone.⁽²⁷⁻²⁹⁾ The closer the implant to the load applied, the more is the strain transmitted to it explaining the reason why there was a statistically significant higher micro-strain records on the loaded side for both attachments utilized in this study.⁽³⁰⁾ Studies have also shown a relationship between the amount of strain transmitted to the bone/implant complex and the type of attachment utilized^(18, 20). The different designs and materials used in each type of attachment have an effect on the amount of stresses received by the peri-implant bone during masticatory loads⁽³¹⁾. Loading was also performed on the first molar as this is considered the center of occlusion where the maximum forces by the elevator muscles occur.⁽³²⁾ Results of this study showed higher strain in the loaded side than the unloaded side in both attachment groups which is agreeable with previous studies performed^(18,32).

Results of this study also demonstrated a statistically significant higher mean micro-strain in the ball attachment in the loaded side than the mean micro-strain of the magnet attachment when subjected to unilateral loading. The ball and socket attachment act as a fulcrum during loading of the overdenture⁽³³⁾ with the lack of any intervening space between its components thus inducing higher strain on the bone/implant complex. This was in accordance with a finite element analysis study which reported high stresses transmitted on

the loading side of ball attachments⁽³¹⁾. The same findings were also recorded on the unloaded side where there was a statistically significant higher mean micro-strain in the ball attachment than the mean micro-strain of the magnet attachment when subjected to unilateral loading which was also explained by a the same study performed .

This study also demonstrated higher statistical significant mean micro-strain values in the loaded side (left side) than the unloaded side in both types of attachments. According to Chao et al. and Mericske-Stern et al^(34,35), the overdenture will tend to rotate anteriorly around a fulcrum line when posterior loads are applied. As a result of this rotation, the denture dis-engaged from the right side thus reduction in the micro-strain transmitted to the right implant.

When comparing the micro strain mean values of both groups while applying strain bilaterally, the study has shown that there was a statistically significant difference in the mean values of micro strain between the Ball and Magnet attachment in the non-loading side where the highest mean value of micro strain was found in Ball attachment while the least mean value of micro strain was found in the Magnet attachment.

Additionally, statistical analysis of the micro strain mean values of both groups while applying strain bilaterally, showed a statistically significant difference in mean of micro strain between the Ball and the Magnetic attachment at the loaded side where the highest mean value of micro strain was found in the Ball while the least mean value of micro strain was found in Magnet attachment. According to Chao et al. and Mericske-Stern et al.^(34, 35), the overdenture will tend to rotate anteriorly around a fulcrum line when posterior loads are applied. As a result of this rotation, the denture dis-engaged from the right side thus reduction in the micro-strain transmitted to the right implant and more micro-strain induction in the left implant. Studies have shown less retentive forces in magnet attachments

in comparison with other stud attachments^(18,36) hence explaining why less stresses were induced in the magnet attachment than the ball attachment⁽¹⁸⁻²⁰⁾. There seems to be an association between the moment an attachment loses its retention and the amount of stresses conveyed to the bone/implant complex; the faster the attachment loses retention, the less the stress transmitted to the implant⁽³⁶⁾.

CONCLUSION

Within the limitations of this study, it can be concluded that ball attachments induced higher micro-strain on the bone implant interface than the magnet attachment. The two main limitations of this study are: the physical properties of acrylic resin do not accurately simulate the complex nature of bone and osseointegration as well as the vertical load that was applied does not resemble the complex directions of forces that occur during mastication. As there is no one attachment that would fulfill the ideal requirements because each clinical situation is unique, careful selection of attachment is necessary to satisfy the patient's needs and expectations, as well as establishing a long term biologic and functional result.

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